CHICAGO, MILWAUKEE & ST. PAUL RAILWAY, BRIDGE NO. Z-2
Chicago Bridges Recording Project
Spanning N. Branch Canal at N. Cherry Ave.
Chicago
Cook County
Illinois

HAER No. IL-143

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

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HISTORIC AMERICAN ENGINEERING RECORD
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HISTORIC AMERICAN ENGINEERING RECORD

CHICAGO, MILWAUKEE & ST. PAUL RAILWAY, BRIDGE No. Z-2

HAER No. IL-143

Location:	Spanning North Branch Canal at N. Cherry Ave., Chicago, Cook County, Illinois.
USGS Quadrangle:	Chicago Loop, Illinois (7.5-minute series).
UTM Coordinates:	16/445630/4639765
Dates of Construction:	1901-02.
Designer:	Chicago, Milwaukee & St. Paul Railway.
Fabricator:	Wisconsin Bridge & Iron Co. (Milwaukee, Wisconsin).
Builder:	Chicago, Milwaukee & St. Paul Railway.
Present Owner:	Canadian Pacific Railroad (Calgary, Alberta).
Present Use:	Railroad bridge.
Significance:	The Chicago, Milwaukee & St. Paul Railway's Bridge No. Z-2 is not only one of few remaining swing bridges in Chicago, but is also of a rare asymmetrical or "bob-tail" type. The pivot pier is on shore rather than at mid-channel, with the resulting asymmetric truss balanced by a concrete counterweight, an early use of that material on a movable bridge. Aligned with Cherry Avenue, the bridge once carried limited vehicular traffic in addition to freight trains, making it perhaps the only surviving bridge in Chicago that once served that combination of modes. The bridge was crucial to the development of Goose Island, carrying the only rail line serving the industries and freight yard there.
Historian:	Justin M. Spivey, January 2001.
Project Description:	The Chicago Bridges Recording Project was sponsored during the summer of 1999 by HABS/HAER under the general direction of E. Blaine Cliver, Chief; the City of Chicago, Richard M. Daley, Mayor; the Chicago Department of Transportation, Thomas R. Walker, Commissioner, and S. L. Kaderbek, Chief Engineer,

Bureau of Bridges and Transit. The field work, measured drawings, historical reports, and photographs were prepared under the direction of Eric N. DeLony, Chief of HAER.

Introduction

Chicago's remaining swing bridges defy a body of twentieth-century engineering literature that considers them unacceptable for urban locations. Swing bridges, nearly ubiquitous among Chicago's river crossings during the nineteenth century, became rare in the twentieth. Old age and structural inadequacy contributed to the need for replacing swing bridges, but more importantly, their mid-channel piers created increasingly unacceptable obstacles to navigation on Chicago's narrow, winding rivers. In the early decades of the twentieth century, swing bridges' slow operation and interference with dock space ensured their replacement with recently developed alternate forms. The U.S. Army Corps of Engineers aided navigation interests by preventing construction of new bridges with mid-channel piers after 1890, and forcing the demolition of existing swing bridges after 1899.

Although swing bridges have nearly disappeared from within city limits, two notable exceptions occur. The first is along the Sanitary and Ship Canal, where waterfront property is not so valuable, nor operating speed so critical, as in downtown Chicago. When the Sanitary District completed the canal in 1899, it carried railroads across the new channel on swing bridges, attesting to their competitive cost of construction and operation.[1] Furthermore, the canal's artificial geometry anticipated the bridges that would span it, so mid-channel piers did not present so great an obstacle. The second exception, on the North Branch of the Chicago River less than two miles from the downtown Loop, is less easily explained. There, the Chicago, Milwaukee & St. Paul Railway (Milwaukee Road) designed and built three swing bridges around the turn of the twentieth century, of which two survive today. The railroad satisfied the requirement for a clear channel by placing the pivot pier on shore, but retained a technology with several undesirable aspects. This paper describes one of the bridges while exploring the

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[1] Even a somewhat biased source, vertical-lift bridge maven J. A. L. Waddell, equivocates about the economy of swing bridges; see *Bridge Engineering,* 2 vols. (New York: John Wiley & Sons, 1916), 1:1208. Swing bridges occupy the lowest positions on his equipment cost graph in ibid., 1:681. H. S. Prichard et al. are more definite on the economic superiority of swing bridges in "Lift Bridges — A Discussion," *Proceedings of the Engineers' Society of Western Pennsylvania* 25, No. 1 (Feb. 1909): 13. Many of the Sanitary & Ship Canal swing bridges survive, and were documented by HAER in its survey of the Illinois & Michigan Canal corridor. See Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior,"Santa Fe Railroad, Sanitary and Ship Canal Bridge," HAER No. IL-39; "Chicago and Western Indiana Railroad Bridge," HAER No. IL-79; and"Chicago, Madison and Northern Railroad, Sanitary and Ship Canal Bridge," HAER No. IL-113, Prints and Photographs Division, Library of Congress, Washington, D.C.

geographical, regulatory, and technological issues surrounding the railroad's persistence in constructing swing bridges.[2]

The Case Against Swing Bridges

Among the variety of movable bridges that rotate, "swing bridge" is the term now commonly used for a span swinging about a vertical axis.[3] The form has no definite recorded origin or inventor, although Waddell did date it as a later invention than the bascule.[4] Unlike more recently developed bascule and vertical-lift forms that received U.S. patents, the swing bridge's long-established design made it essentially unpatentable. (As will be shown later, this was a key factor in the Milwaukee Road's continued use of swing bridges.) Swing bridge construction in Chicago was therefore not affected by the patent-infringement litigation that characterized the city's later efforts to build bascule spans.

The sudden demise of Chicago's swing bridges within the first two decades of the twentieth century is even more remarkable considering their previous proliferation. During the nineteenth century, most — if not all — railroads used swing bridges on their lines into Chicago. Swing bridges dominated among movable spans for railroads because of their "simplicity and low cost of ... construction and operation."[5] The tight budgets of early American railroads may have suppressed experimentation with alternate forms. Familiar designs for wood or iron trusses could be easily adapted to movable spans, perhaps taking advantage of material savings from structural continuity over the center pier. This, however, resulted in many members carrying different forces in the bridge's open and closed positions. Alternatively, breaking continuity over the pivot resulted in two simple truss spans, thus simplifying design calculations.[6] The

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[2] The other surviving bridge is described in a separate report, Justin M. Spivey, "Chicago, Milwaukee & St. Paul Railway, Bridge No. Z-6," HAER No. IL-162. A third swing bridge, since demolished, crossed the North Branch of the Chicago River, at an extreme skew, north of the city's Kinzie Street Bridge. This highly unusual span pivoted about the midpoint of its western truss, and is described in Otis E. Hovey, *Movable Bridges,* 2 vols. (New York: John Wiley & Sons, 1926), 2:55.

[3] The issue of terminology is complicated by the traditional use of "drawbridge" to mean any movable bridge, and then, during the nineteenth century, to mean vertical-axis swing bridges exclusively. Waddell uses the term "rotating draw" for vertical-axis swing bridges in *Bridge Engineering* and in *De Pontibus: A Pocket-Book for Bridge Engineers,* 1st ed. (New York: J. Wiley & Sons, 1898), while the U.S. Army Corps of Engineers sometimes uses "swing bridge" in reference to horizontal-axis bascule spans in its annual reports. For example, "swing bridge for the first-named road" in U.S. Army, Corps of Engineers, *Report of the Chief of Engineers, U.S. Army, 1912* (Washington, D.C.: U.S. Government Printing Office, 1913), 2:2547, refers to the Baltimore & Ohio Chicago Terminal Railroad's Strauss heel-trunnion bascule over the Calumet River.

[4] Waddell, *Bridge Engineering,* 1:668.

[5] Prichard et al., "Lift Bridges," 13.

[6] See Prichard et al., "Lift Bridges," 13-14. "Arthur Hill, on Staten Island," might be a typographical error for Arthur Kill.

heavy, dynamic loads imposed by trains undoubtedly influenced railroads' preferences for swing bridges. Through trusses, even if mounted on a pivot, retain stiffness from four connected planes of trussing. Railroads' demands for rigid structures excluded experimental folding and collapsible designs, whose hinges introduced unwanted flexibility.[7] Finally, swing bridges do not permit closely parallel tracks, which became an issue when traffic necessitated four-track lines. Only during the last decade of the nineteenth century, and the first decade of the twentieth, did swing bridges' drawbacks begin to outweigh their advantages.

These drawbacks became apparent when railroads were faced with external demands for wider and straighter river channels, in addition to their own needs for heavier trains and additional parallel tracks. The external demands came from those Chicago industries dependent on river trade, which plied the city's waterways in ever-larger craft. As stated in an 1897 analysis of obstructions in the Chicago River, "The dimensions of the river some thirty years ago were ample for the commerce and traffic of that time.... Almost everything in the city [has] been 'kept up with the times' — except the river."[8] The report, presented to the Western Society of Engineers in June 1898, carried the weight of more than opinion. The speaker was G. A. M. Liljencrantz of the U.S. Army Corps of Engineers' Chicago District, which had recently become the powerful federal ally of Chicago industries shipping on the river.

The Army Corps' role in Chicago River navigation increased throughout the nineteenth century. Although the Army began improving the Chicago River in 1833, when soldiers at Fort Dearborn first attempted to straighten the river where it entered Lake Michigan, it did not use federal appropriations for improvements beyond the river's mouth until 1896.[9] During this time the agency did exert some control over the river, although one annual report hints that the Chicago District had trouble enforcing a "mandate" regarding the city's Canal Street Bridge and laws against dumping in the river.[10] Toward the century's end, however, declining river trade highlighted the Chicago River's problems. The district engineer's recommendations against new bridges with mid-channel piers appear to have effectively prevented their construction after

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[7] See Prichard et al., "Lift Bridges," 14-15, for an example of the collapsible form that Waddell, in *Bridge Engineering,* 1:665, called the "horizontal-folding draw." In ibid., 1:668, Waddell condemned "jack-knife or folding bridges" as "a freak design."

[8] G. A. M. Liljencrantz, "Obstructive Bridges and Docks in the Chicago River," *Journal of the Western Society of Engineers* 3, No. 3 (June 1898): 1056.

[9] Congress first asked the Chicago District engineer to report on potential river improvements in 1892, and began to provide funding with the River and Harbor Act of 1894; see U.S. Army, Corps of Engineers, *Annual Report ... for the Year 1897* (Washington, D.C.: U.S. Government Printing Office, 1898), 2:2794. This money was not used until 1896, however; see ibid., *Annual Report ... for the Year 1901* (Washington, D.C.: U.S. Government Printing Office, 1902), 1:529.

[10] U.S. Army, Corps of Engineers, *Annual Report ... for the Year 1893* (Washington, D.C.: U.S. Government Printing Office, 1894), 4:2799.

1890.[11] The River and Harbor Act of 1899 gave the Secretary of War authority to order bridges removed, and imposed his approval as a necessary step in constructing bridges over navigable waterways.[12] With Liljencrantz's survey, "Obstructive Bridges and Docks in the Chicago River," the stage was set for the Army Corps to clear swing bridges from the river.

The Army Corps' work on the Chicago River during the first decades of the twentieth century not only consisted of dredging channels and stabilizing banks, but also included a heavy component of removing obstructions. Acting upon petitions from navigation interests concerning the latter, it held public hearings, the dates of which are listed in annual reports throughout the peak years of bridge replacements. Usually the outcome of these hearings was the Secretary of War's order that a bridge be removed. Of the railroad bridges studied in the Chicago Bridges Recording Project, the Army Corps had identified all six as obstructions to navigation. It is worth studying other railroads' strategies for bridge replacement as a context for the Milwaukee Road's two swing bridges.

Alternatives to Swing Bridges

In his exhaustive dissertation on the evolution of Chicago's railroad network, geographer and Chicago regional planner Harold M. Mayer identified "seven railway approaches to Chicago," or groups of railroad lines into the city.[13] These give a representative sample of swing bridge replacements on major river crossings, many of which have been documented by HAER. Mayer numbered his railway approaches from northwest to southeast, starting with the North Branch of the Chicago River. Where the Chicago & North Western Railway (C&NW) line from Milwaukee crosses the North Branch, a two-track swing bridge persisted until 1916, when a three-track Strauss heel trunnion bascule replaced the "worn out" structure.[14] Several railroads share the second approach, along the line of Kinzie Street, but only the C&NW crosses the river. The C&NW's Kinzie Street swing bridge, one of the nation's first steel bridges when constructed in 1879, was replaced by a Strauss overhead trunnion bascule after only thirty years of service.[15] Although the Army Corps of Engineers had identified this as an obstruction to navigation, C&NW seems to have replaced the bridge for structural and operational reasons before the

[11] U.S. Army, Corps of Engineers, *Annual Report ... for the Year 1900* (Washington, D.C.: U.S. Government Printing Office, 1901), 5:3869.

[12] "An Act Making appropriations for the construction, repair, and preservation of certain public works on rivers and harbors, and for other purposes," 3 Mar. 1899, *Statutes at Large* 30 (1899), 1121 et seq.

[13] Harold M. Mayer, "The Railway Pattern of Metropolitan Chicago" (Ph.D. diss., Univ. of Chicago, 1943).

[14] O. F. Dalstrom, "The 186 Foot Bascule Bridge of the C. & N. W. Ry., over the North Branch of the Chicago River at Deering," *Journal of the Western Society of Engineers* 22, No. 7 (Sep. 1917): 453-78.

[15] Thomas J. Misa, *A Nation of Steel: The Making of Modern America, 1865-1925* (Baltimore: Johns Hopkins Univ. Press, 1995), 75; cf. Justin M. Spivey, "Chicago & North Western Railway, Kinzie Street Bridge," HAER No. IL-142.

Secretary of War officially demanded its removal.[16] These instances of swing bridges wearing out before replacement are rare, however, considering that the remainder of bridges studied were replaced at the Secretary of War's behest.

That the C&NW chose patented movable bridge designs, both by Joseph B. Strauss, for its two major river crossings follows an overall pattern. When pressed to replace their bridges, Chicago railroads — except the Milwaukee Road — chose recently developed movable bridge designs that offered a smaller footprint, greater economy of material, and quicker operation than swing bridges. The patents for these new designs were often controlled by engineers (or, in the case of the Rall bascule, by a contractor) who collected royalties for their use. After several experimental installations proved their worth, successful movable bridge patents saw repeated — or even exclusive — use along a given railroad line. Strauss bascules and Waddell vertical-lift bridges were especially popular among railroads entering Chicago, which were evidently willing to trade royalty payments for proven reliability. The first Waddell lift bridge at Halsted Street received an explicit endorsement from the Army Corps of Engineers, an added bonus.[17] On the remainder of major railway approaches identified by Mayer, railroads replaced bridges in direct response to orders from the Secretary of War, and in every case used a patented design (see Table 1).

Table 1. Patented movable bridge designs along Mayer's railway approaches to Chicago.

Approach	Railroad	Crossing	Design	Date
1	Chicago & North Western	N. Branch of Chicago R.	Strauss heel trunnion bascule	1916
2	Chicago & North Western	N. Branch of Chicago R.	Strauss overhead trunnion bascule	1909
3	B&O Chicago Terminal	S. Branch of Chicago R.	Strauss heel trunnion bascule	1930
	St. Charles Air Line	S. Branch of Chicago R.	Strauss heel trunnion bascule	1919
4	Chicago & Alton	S. Fork of S. Branch	Page bascule	1906
5	Pittsburgh, Fort Wayne & Chicago	S. Branch of Chicago R.	Waddell vertical-lift	1915
		Calumet R.	Waddell vertical-lift	1913
6	Lake Shore & Michigan Southern	Calumet R.	Waddell vertical-lift	1914
7	Illinois Central	Calumet R.	Strauss bascule with counterweight underneath	1925

Given other railroads' overwhelming preference for the superior characteristics of patented designs, it seems unusual that the Milwaukee Road, when ordered to remove its swing

[16] See Spivey, "Chicago & North Western Railway, Kinzie Street Bridge," HAER No. IL-142.

[17] U.S. Army, Corps of Engineers, *Annual Report ... for the Year 1900,* 5:3869.

bridges, replaced them with the same technology, albeit in a different configuration that satisfied the War Department's requirements. Although the royalties charged for patented designs presented an economic disincentive to their use, the railroad also had to consider the inherent disadvantages of swing bridges: a large footprint, less economical use of material, and slow operation. The Milwaukee Road's two swing bridges in Chicago are explained by the limited geography of its lines, its ability to obtain War Department approval, and the technological abilities of its Bridge and Building Department.

Goose Island's Only Railroad

Exploring the geographical reasons why the Goose Island site supported the persistence of swing-bridge technology requires an excursion into the area's history. Throughout the twentieth century, a predominantly industrial area has existed northwest of Chicago's skyscraper core. Seeking new sites with direct access to water transportation, lumber, metal, and fuel trades spread up the North Branch of the Chicago River during the late nineteenth century. Although the advancing front of development had yet to reach the area, a man-made channel, named Ogden Canal after its primary backer, opened up additional water frontage in the 1850s. Bridge No. Z-2 owes its existence to the canal (since renamed North Branch Canal), which cuts off a series of bends in the river and isolates the land mass known as Goose Island. Once crowded with industry, the island still supplies a limited amount of freight traffic today, from companies such as Akzo Salt, Big Bay Lumber, and Midwest Industrial Metals.[18] These customers are accommodated by Canadian Pacific Railroad trains crossing a single-track swing bridge. In fact, the single track has been Goose Island's only railroad connection since the 1870s.

A reading of Chicago's early history reveals the name William B. Ogden, likely in more than one context. Indeed, Ogden seems almost omnipresent in Chicago after his arrival in June 1835: selling real estate, contracting on the Illinois & Michigan Canal, presiding over the first successful railroad (which later became the C&NW) — not to mention serving as the city's first mayor. His ceaseless promotion of "public improvements" undoubtedly raised land values (among his own holdings if not elsewhere). One biography endows him with earth-moving omnipotence: "He made many rough places smooth, and the crooked ways straight."[19] Amidst the flattery, however, most biographers have little to say about what may be Ogden's most significant impact on Chicago geography, the canal that bears his name. One contemporary source states that Ogden's Chicago Land Company constructed the canal between 1853 and 1857, selling bricks made from the excavated clay. City maps show the canal completed as early

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[18] Tom Burke, "Milwaukee Road: Knocking at Chicago's Back Door," *Milwaukee Railroader* (3rd Quarter 1995): 16-18, Milwaukee Road Collection, Milwaukee Public Library, Milwaukee, Wis. (hereinafter cited as MRC).

[19] Isaac N. Arnold and J. Young Scammon, *William B. Ogden,* Fergus Historical Series No. 17 (Chicago: Fergus Printing Co., 1882), 46.

as 1855, which may represent a prediction rather than truth.[20] More importantly, largely empty blocks reflect real estate speculators' practice of laying out Chicago's street grid far in advance of development. In the meantime, the lots were squatted upon by Irish immigrants whose geese gave the island its name.[21]

One railroad served land along the North Branch in 1855, the Chicago & Milwaukee Railroad (later C&NW) line on its west bank.[22] Competition did not arrive until 1871, when the Atlantic & Pacific Railroad began constructing a line westward from Goose Island; the name was changed to Chicago & Pacific (C&P) the following year. As with many Midwestern railroads, insufficient local capital meant that eastern investors purchased most of the construction bonds issued by the line. Lackawanna Iron & Coal and the Delaware, Lackawanna & Western Railway, both Pennsylvania companies, backed the C&P — and took a hit when it declared bankruptcy in 1880.[23] The Milwaukee Road then had sufficient financial resources to purchase the C&P from its creditors. Local freight traffic from Goose Island, on the Milwaukee Road and its successors, has used the C&P line ever since.[24]

Two years later, in 1882, the Milwaukee Road's directors and several New York investors purchased the charter of the Chicago & Evanston Railroad (C&E).[25] They soon began constructing the C&E line in Kingsbury Street, parallel to the North Branch Canal on its east side, then northward to Wilmette. Although the Milwaukee Road absorbed the C&E in 1887, the point where it meets the C&P's Goose Island line is still known as C&E Junction.[26] Both lines remain at street level, among the few railroads in downtown Chicago not forced onto a grade-separated alignment by the city's track elevation ordinances. The area served by the former C&P and C&E lines is predominantly industrial, where street-level tracks were necessary to serve freight customers, and not so critical a public safety issue as in residential neighborhoods. Unlike other Chicago locations where railroads constructed vertical-lift bridges to accommodate

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[20] Perry R. Duis and Glen E. Holt, "Chicago's Only Island," *Chicago* (Feb. 1979): 170, MRC. The author is grateful to Jeffrey A Hess for discovering J. H. Colton & Co., "[Map of] the City of Chicago Illinois" (Chicago, 1855, reprint, Chicago: Rand McNally, n.d.), Reference Collection, Chicago Historical Society, Chicago, Ill.

[21] Duis and Holt, "Chicago's Only Island," 172.

[22] The Illinois & Wisconsin Railroad shared this line, built in 1854, between Chicago and Clybourn Junction; see Mayer, "Railway Pattern," 80.

[23] John W. Cary, *The Organization and History of the Chicago, Milwaukee & St. Paul Railway Company* (Milwaukee: Press of Cramer, Aikens & Cramer, 1892; reprint, New York: Arno Press, 1981), 253-54.

[24] Mayer, "Railway Pattern," 82.

[25] Cary, *Organization and History,* 258.

[26] Chicago Operating Rules Association, "Map of Chicago Terminal District" (Chicago, 1998).

future track elevation, the Milwaukee Road could install a swing bridge with confidence that its tracks would stay put.[27]

Even though shipping on the Chicago River and its branches declined in favor of year-round connections provided by railroads, industry remained along the rivers. According to Mayer, the Chicago River's North and South branches remained important industrial areas "long after navigation on the rivers became relatively unimportant as a factor in the localization of industry."[28] This is certainly true in the vicinity of Goose Island, where tracks paralleled both river and canal, providing rail service to virtually every site with water access. Furthermore, although Ogden's canal ostensibly provided a straighter waterway than the winding river, the canal was obstructed by the Milwaukee Road's bridge until the latter was replaced in 1902.

An Army Corps of Engineers survey in 1928 provides a satisfactory characterization of the island during the early twentieth century: packed to the hilt.[29] The Milwaukee Road's freight yard is the dominant feature of the map, consuming the bulk of the island's interior area. Four grain elevators, including those built by financier Philip D. Armour during the "grain wars" of 1887 and 1893, occupy the northeastern waterfront.[30] Assorted industries surround the freight yard on all sides, including three tanneries; a steel mill; manufacturers of oil, varnish, paper, boxes, and mattresses; and yards for coal, sand, and gravel. One business worthy of mention by name is the Great Lakes Dredge & Dock Company, which built foundations for many bridges in Chicago. Even so, one rail line with a single track sufficed to serve the island, the limited area of which guaranteed a finite amount of traffic. Unlike railroads elsewhere in Chicago, the Milwaukee Road's Goose Island spur did not see enough of an increase in traffic at the beginning of the twentieth century to justify an additional track. Nor was it necessary to replace a swing bridge with a faster-operating design. Traffic on the line was exclusively freight, which would abide a longer wait without complaint.

The War Department Changes Its Mind

The complaint against the Milwaukee Road's swing bridge, then, came not from rail traffic along the line, but from water traffic beneath it. The city of Chicago had been complaining for decades about crowded conditions on the "torturous little creek" otherwise

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[27] For more about vertical-lift bridges and track elevation, see Justin M. Spivey, "Pittsburgh, Fort Wayne & Chicago Railway, Calumet River Bridge," HAER No. IL-156.

[28] Mayer, "Railway Pattern," 89.

[29] U.S. Army, Corps of Engineers, "Chicago River, Ill., and Its Branches, in 11 Sheets" (Chicago, 1928), sheet 3, project files, Chicago District, U.S. Army Corps of Engineers, Chicago, Ill. (hereinafter cited as USACE Project Files).

[30] Duis and Holt, "Chicago's Only Island," 172.

known as the Chicago River.[31] This reflected fears that obstructive bridges were causing a decline of water-borne trade. Army Corps of Engineers surveys of the river placed the Milwaukee Road's three swing bridges over the North Branch among the worst obstructions. Indeed, these were among the first center-pier railroad swing bridges in Chicago to be replaced by alternate forms. Whereas other railroads used patented bascule and vertical-lift designs, the Milwaukee Road simply modified existing swing-bridge technology to meet the new requirements.

Although the War Department found the Milwaukee Road's center-pier swing bridges to be obstructive, it is unclear whether the Secretary of War ever ordered their removal. The Corps of Engineers' annual report for 1901 mentions only a permit granted to rebuild Bridge No. Z-2, indicating that the railroad might have anticipated a forced removal.[32] Analysis of a similar bridge upstream provides evidence in favor of this argument. An 1899 article about nearby Bridge No. Z-6 refers to its "somewhat deteriorated condition," hinting that the ten-year-old bridge needed replacement anyway. According to that article's author, "As it was decided to renew the bridge with a new type of structure advantage was taken of the opportunity to improve the river channel at this point."[33] In Bridge No. Z-6, structural obsolescence preceded the Army Corps' power to demand its removal. Returning to the Goose Island bridge, a similar situation may have transpired. A photograph of Bridge No. Z-2's forerunner in *Railway Age* shows a similar wooden Howe truss, this one twice as old.[34] Again deciding to replace a center-pier swing bridge with a bob-tail design, the Milwaukee Road submitted plans to the War Department.

The permit application for Bridge No. Z-2 actually crossed the Secretary of War's desk twice. On the first pass, in September 1900, the Milwaukee Road submitted a plan for a bob-tail swing bridge with arms of 124'-0" and 68'-7-1/2", providing a clear channel width of 100'-0". Because the established dock lines were about 150 feet apart, the railroad proposed placing the pivot pier in the channel, behind a line of guard piles projecting 50 feet from the north dock line. Acting Secretary of War G. D. Meiklejohn found this arrangement acceptable, and signed the permit on 19 December 1900. The Milwaukee Road was likely not ready to begin construction

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[31] See, for example, Chicago Department of Public Works, *Eighth Annual Report* (Chicago, 1883), 38-44, Municipal Reference Collection, Chicago Public Library, Chicago, Ill.

[32] U.S. Army, Corps of Engineers, *Annual Report ... for the Year 1901* (Washington, D.C.: U.S. Government Printing Office, 1902), 1:665.

[33] "New Form of Plate-Girder Swing Bridge, C. M. & St. P. Ry.," *Railway & Engineering Review* 39, No. 43 (28 Oct. 1899): 604.

[34] "A Counterbalance Swing Bridge on the Chicago, Milwaukee & St. Paul," *Railway Age* 33, No. 10 (7 Mar. 1902): 291.

right away, however, given the risk of preparing detailed plans for a bridge that might be rejected by the War Department.[35]

As it turns out, the bridge approved in 1900 was never constructed. Instead, the Army Corps of Engineers' project files contain a second plan and permit for a bridge at this location, which outline the bridge's geometry as built. The revised plan is dated only a month after the first permit was signed. Existing evidence does not provide a definite reason why the War Department withdrew its approval of the Milwaukee Road's first proposal. The second permit bears a different signature, that of Secretary of War Elihu Root. Office politics may be a tempting explanation for Root's reversal of the acting secretary's decision, but this is a hasty conclusion. Two changes appear in the second plan, which (though also neatly drawn) does not include as many details as its predecessor. First, the clear channel width increased to 120'-0", spanned by a bob-tail swing bridge with arms of about 140 and 85 feet.[36] More importantly, the plan shows the pivot pier on shore behind the north dock line. A trapezoidal projection from the south dock line, about 30 feet wide, forms the opposite abutment. In the previous arrangement, the guard piles not only presented a larger obstacle, but also because of their placement on the outside of a bend in the canal, would have required barges to negotiate a tighter turn. The second plan maintains the maximum turning radius, and is therefore the superior design. The War Department's approval came on 19 February 1901, and thirteen months later *Railway Age* reported that "the substructure is now nearly completed."[37]

The Milwaukee Road's Bridge and Building Department

Railway Age, always thorough in crediting all parties responsible for a project, does not name a foundation contractor for Bridge No. Z-2. This is no omission; the Milwaukee Road's own bridge department performed the work. Herein lies the most influential reason for the technological inertia of swing bridges. Because the railroad's Bridge and Building Department had experience in designing, erecting, and maintaining swing bridges, it was easier to push the limits of an existing form than to begin using a new one.

Many of the Milwaukee Road's administrative departments demonstrated an almost stubborn independence. One railroad historian noted that the company continued to build its

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[35] Chicago, Milwaukee & St. Paul Railway, Bridge and Building Department, "Proposed Bridge over North Branch Canal — Chicago," drawing No. A-227 (29 Sep. 1900) and accompanying permit (19 Dec. 1900), Chicago River Sheet No. 50, USACE Project Files.

[36] These dimensions are not explicitly labeled on the plan, but were scaled from labeled lengths. See Chicago, Milwaukee & St. Paul Railway, Bridge and Building Department, "Proposed Bridge over North Branch Canal — Chicago. 120 ft. Clear Opening," drawing No. A-356 (21 Jan. 1901) and accompanying permit (19 Feb. 1900), Chicago River Sheet No. 65, USACE Project Files.

[37] "A Counterbalance Swing Bridge," 290.

own cars long after other railroads began buying standard cars from manufacturers.[38] Railroad and engineering periodicals repeatedly reminded their readers of this policy, to which the Bridge and Building Department was no exception. An editor's note appended to one article stated, "The Chicago, Milwaukee & St. Paul Ry. does practically all its bridge work by its own forces."[39] Equipment used by the department was largely of its own design. While researching this report, the author found articles describing custom-made derrick cars and cement mixers used for bridge construction.[40] When the Bridge and Building Department confronted the task of replacing Bridge No. Z-2, it may not have even considered paying royalties for patented designs before making plans for a bob-tail swing bridge.

Given the Milwaukee Road's penchant for designing and erecting its own bridges, one might expect the railroad to have fabricated them, too, but this was not the case. Although a railroad might obtain favorable rates for steel shipped along its lines, as the Pennsylvania Railroad learned from its vertical integration with the Pennsylvania Steel Company, the net cost of a "captive" mill's produce could end up higher than purchases made from independent mills.[41] For whatever reason — competitive pricing, intermittent demand, or the difficulties of making steel — the Milwaukee Road chose to pay the lowest bidder on a bridge-by-bridge basis rather than integrate a steel mill into its operations. According to an article in *Railroad Gazette,* the railroad chose Wisconsin Bridge & Iron Company to fabricate the steel members for Bridge No. Z-2. That fabricator's Milwaukee location, with the potential for shipping over Milwaukee Road tracks, may have helped its successful bid in this case.[42] But the Milwaukee Road was not exclusively loyal to one fabricator, or even to fabricators along its own lines, for steel work. American Bridge Works of Chicago, for example, had fabricated another bob-tail swing bridge for the Milwaukee Road two years previous. The railroad also contracted out dredging and dock work on that bridge, indicating further exceptions to the in-house rule.[43]

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[38] Nick Callas, president of Illinois Railway Museum, telephone conversation with author, 30 July 1999.

[39] Editor's note in H. C. Lothholz, "Replacing Worn Bridge Pins in the Field," *Engineering News* 67, No. 4 (25 Jan. 1912): 153.

[40] "New Bridge Derrick Cars; Chicago, Milwaukee & St. Paul," *Railroad Gazette* 44, No. 11 (13 Mar. 1908): 362-63; "A Counterbalance Swing Bridge," 291; see also Lothholz, "Replacing Worn Bridge Pins," 153, for modifications to stock equipment.

[41] Misa, *Nation of Steel,* 22n.

[42] *Railway Age*'s article, printed one week earlier, credited "the Wisconsin Bridge Company" with the fabricating work. Although companies named Wisconsin Bridge & Iron (of Milwaukee) and Wisconsin Bridge (of Prairie du Sac) both existed in that state in 1901, it is likely that *Railway Age* simply omitted "& Iron" from the fabricator's name. See Victor C. Darnell, *A Directory of American Bridge-Building Companies, 1840-1900,* Occasional Publication No. 4 (Washington, D.C.: Society for Industrial Archeology, 1984), 75.

[43] See Spivey, "Chicago, Milwaukee & St. Paul Railway, Bridge No. Z-6," HAER No. IL-162.

Structural Description

The bob-tail swing bridge concept was at least four centuries old when it arrived in Chicago; sketches of two bob-tail swing bridge designs appear in da Vinci's *Codice Atlantico*.[44] Timeless as it may be, this variant has most of a symmetrical swing bridge's disadvantages, as well as some of its own. Nonetheless, the Milwaukee Road used the bob-tail form to great success twice in Chicago, on sites which forgave some of these technical defects. Bridge No. Z-2 is described here.[45]

This bridge has a pivot pier on shore, with one long truss arm spanning the channel while balanced by with a shorter, heavier counterweight arm. The bob-tail's counterweight, hung from a truss above the deck, takes up less space on shore than would a symmetrical arm. Although the river arm still consumes some dock space, this was not a critical fault at the Goose Island site. Here, the North Branch Canal flows from west to east, closely parallel to North Avenue. It is unlikely that property thus constrained would be occupied by any industry needing dock space. (Indeed, the Army Corps of Engineers' 1928 survey shows an empty lot.) Regardless, an article describing the bridge boasted, that the counterweight "is 20 feet above the level of the tracks, thus leaving the space under the truss available for dock purposes."[46] The strength of this point is somewhat reduced because the bridge swings to the east, bringing the counterweight over a smaller and less useful lot to the west.

The bridge swings to the east because doing so requires a smaller angle of rotation than swinging to the west. Maps and drawings show the north dock wall at an 82.5-degree angle to the Milwaukee Road tracks, with the acute angle in the southeast quadrant. This is important for bob-tail swing bridges because, unlike symmetrical swing bridges, they cannot rotate through an angle of 360 degrees, closing behind a boat as it passes through.[47] The operator of a bob-tail swing bridge must wait for boats traveling in the swing direction to clear the river arm completely before closing the bridge. Bridge No. Z-2's eastward swing, though fifteen fewer degrees per opening, provides a marginally faster operating time than would a westward swing.

To span the dimensions dictated by the Army Corps, the railroad selected the through truss shown schematically in Figure 1, which measures 230'-0-1/4" between endmost pins, and 43'-0" high, pin-to-pin, at its tallest point. The trusses are spaced 17'-0" on center, wider than the average one-track railroad bridge. The *Railway Age* article provides the reason for this: "The

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[44] Leonardo da Vinci, *Il Codice Atlantico nella Biblioteca Ambrosiana di Milano* (riprodotto, Milano: Regia Accademia dei Lincei, 1894), cited in Hovey, *Movable Bridges,* 1:5. Another interesting example is a self-closing "counterbalanced" design used over a canal in Bordentown, N.J.; see Prichard et al., "Lift Bridges," 14.

[45] The other, Bridge No. Z-6, is the subject of Spivey, "Chicago, Milwaukee & St. Paul Railway, Bridge No. Z-6," HAER No. IL-162.

[46] "A Counterbalance Swing Bridge," 291.

[47] Lee Treadwell, in discussion following J. A. L. Waddell, "The Halsted Street Lift-Bridge," *Transactions of the American Society of Civil Engineers* 33 (1895): 40.

roadway will be floored over, allowing for the passage of fire engines to the island across the bridge."[48] This is a helpful feature because Goose Island's bridges have traditionally been clustered toward the south end. Although it is not used for vehicular traffic at present, Bridge No. Z-2 might well be Chicago's only surviving bridge designed to carry both a city street (Cherry Avenue) and heavy rail. The bridge also carries a wooden sidewalk cantilevered 5'-2-1/2" from its east side, perhaps intended for workers commuting on foot to Goose Island. A railing of steel posts and wooden stringers protects the sidewalk.

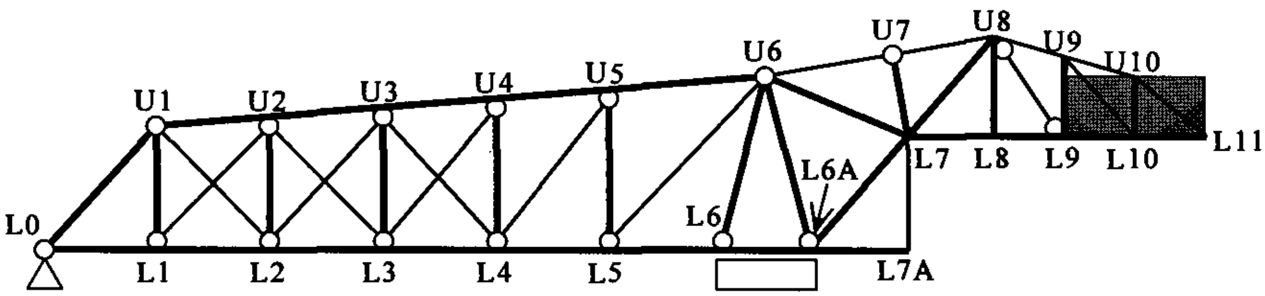

Figure 1. Reference for panel point numbers on Bridge No. Z-2 (not to scale), with concrete counterweight shown in grey tone. Sketch by author.

The river arm of the truss follows a straightforward Pratt design, with six panels each 22'-5" long, or 134'-6" from L0 to L6. Although the archetypical Pratt truss has two tension diagonals crossing each panel to form an "X," later variants contained some or all single-diagonal panels. The river arm's pattern of diagonals is worthy of note, for it reflects the two loading conditions for which the truss was designed. Were this bridge a fixed span, diagonals U2-L1 and U3-L2 would not be necessary for carrying loads (although they do increase stiffness for asymmetrical loading conditions). These diagonals are needed, however, when the bridge swings off its support at L0. Recalling that the diagonals cannot carry significant compressive forces, diagonals U1-L2 and U2-L3 would buckle in this situation, collapsing that end of the truss, were it not for the opposing diagonals in those panels.

The river arm of the bridge, in addition to having inclined end-posts, also has an inclined upper chord. This reflects an efficient use of material to carry the cantilever loading when the bridge is open. The upper chord rises from 25'-0" above the lower chord at U1, to 35'-0" at U6. Panel point U6 is the apex of a triangle, 17'-0" wide at the base, which is supported on the pivot drum below. The upper chord's inclination is not unlike many symmetrical swing bridges, where it creates an efficient cantilever truss when open or variable-depth truss continuous over one support when closed. The Milwaukee Road's design for Bridge No. Z-2 is different, however, in replacing one arm of the swing bridge with a concrete counterweight. Placing the counterweight as far as practicable from the pivot reduces the necessary weight of concrete,

[48] "A Counterbalance Swing Bridge," 290.

although requiring a substantial amount of metal in its own truss arm.[49] The overall profile of the bridge, with its large concrete counterweight suspended above the tracks, has led some rail enthusiasts to conclude that Bridge No. Z-2 is a bascule bridge.[50] Unlike a bascule bridge, where the span and counterweight move relative to each other, however, the river and counterweight arms of Bridge No. Z-2 are connected in one continuous truss.

The counterweight arm does not continue the Pratt pattern of the river arm because some of its diagonals exceed the vertical members in bulk, indicating the diagonals' role as primary compression members. Also, eye-bar links (capable of carrying mainly tensile forces) replace the top chord between U6 and U8. That the top chord is elsewhere a compression member indicates the reversal of forces caused by structural continuity over the pivot. The bridge's bulkiest compression member extends from L6A, through L7, to the truss's maximum height at L8, where it is tied back by the aforementioned eye-bar links. Directly below panel point L7 hangs L7A, which supports the north end of the movable deck. The inclined end-post L11-U10 is partially embedded in the concrete counterweight that occupies the last panel of the truss. Perpendicular to L10-L11, 15"-deep, 41-pound I-beam sections span between the trusses to support the counterweight.

The beams supporting the counterweight are among the few rolled I-beam sections in the bridge. Elsewhere, construction is typical late nineteenth-century construction using built-up members riveted together from rolled plates, angles, channels, and lacing. The upper chord is two back-to-back channels with a cover plate on top and double lacing below. Simply supported trusses of this vintage have eye-bar lower chords suited for purely tensile forces. In a swing bridge, however, the lower chord goes into compression when the bridge is open, requiring a box section similar to the upper chord (though with lacing both top and bottom). The river arm's upper- and lower-chord members use 15"-deep channels of various weights, and are continuous across panel points. Cover plates reinforce holes at the panel points, which accept pins for connections with vertical and diagonal members. Diagonals in the river arm are typically of eye-bar construction, with turnbuckle adjustments in U1-L2, U2-L3, and U3-L4. With cross-bracing in the upper and lower planes, riveted plate-girder floor beams and stringers, and a bit of flair in the portal bracing's curved brackets, the river arm is of typical truss construction for the time.

Structural details begin to diverge from typical in the counterweight arm. As stated before, the bridge's largest compression member is L6A-U8, with an impressive cross-sectional area of almost 50 square inches. At panel points L7 and U8, the bridge's designers placed riveted connections with large gusset plates that stand out against the pin-connected river arm.

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[49] The concrete counterweight, by its larger size, has a greater surface area than would an iron counterweight. This may help balance the "moments of the wind pressure" acting on each arm, as recommended by Waddell in *De Pontibus,* 104. Limitations in the scope of this report prevented a calculation of these moments.

[50] Stanley A. Changnon, *Railroad Bridges in the Heartland* (Champaign, Ill.: Printec Press, 1997), 187; Burke, "Milwaukee Road: Knocking at Chicago's Back Door," 14.

North of eye-bar member U8-L9, the counterweight arm has riveted connections exclusively. While pinned joints allow members to rotate relative to each other, fixed connections (such as those riveted to gusset plates) provide bending resistance at the joint. This has consequences in structural analysis, namely that a pinned joint has one fewer equation of equilibrium than a fixed one, simplifying calculations. The fixed connection, however, provides additional buckling resistance to compression members attached to it, and greater rigidity to the truss overall. Given the analytical tools of late nineteenth-century bridge engineers, the truss was likely analyzed as a pin-connected structure, with the fixed joints assumed to provide an additional factor of safety in the counterweight arm.

Nineteenth-century American engineers and bridge companies preferred pin-connected trusses because they were easier to design and build. Compared to all-riveted joints, pinned connections required less work in the field. The Milwaukee Road encountered one drawback of pin-connected trusses in Bridge No. Z-2. When bridges are subjected to cyclical loads, such as those imposed by opening and closing the span or trains passing over it, the back-and-forth rotation of members can wear down pins. Less than a decade after completing the structure, the Milwaukee Road's bridge crew found itself back on site, replacing worn pins at L0 and U1.[51] After securing members to temporary brackets, the crew removed the existing 5"-diameter pins, enlarged the holes, and inserted new 5-1/2"-diameter pins. This procedure, performed in the field, provides yet another example of Milwaukee Road engineers' creativity.

Mechanical Description

Bridge No. Z-2 differs most notably from its contemporaries in its lifting, locking, and rotating mechanisms. Before these can be described, their place in the operating procedure must be understood. The rail lifts are activated first. Because the rails on the bridge have scarfed ends that extend past the ends of the movable span, they must be lifted slightly when the bridge is moving or open. Rail lifts push the rails from beneath to a height at which they clear the scarfed ends of the fixed rails on the abutments. (Scarfed joints allow thermal expansion and contraction, forming a smooth transition between fixed and movable rails in any weather.) After the span lock draw-bar is lifted, the end lift shoes are rotated clear of their seats, allowing the span to dip slightly toward its free end. The operator engages the rotating mechanism, cutting power as the bridge nears its open position, and applying the brake if necessary. This procedure is reversed to close the bridge: rotate, brake, rotate the end lift shoes onto their seats, drop the draw-bar, and drop the rails.

The Milwaukee Road's engineers devised a unique arrangement for Bridge No. Z-2's lifting and locking mechanisms. While contemporary textbooks on movable bridge design showed wedges driven to lift the end of the bridge to its proper elevation and to lock it in place,

[51] "Replacing Pins in a Bridge in Service," *Engineering Record* 64, No. 27 (30 Dec. 1911): 771; Lothholz, "Replacing Worn Bridge Pins," 152-3.

the Milwaukee Road's swing bridges have separate mechanisms for these two functions.[52] At the free end, cam-shaped end lift shoes rotate about an axis perpendicular to the tracks. Because the profile of the end lift shoe is eccentric to its axis of rotation, turning the shoe raises or lowers the end of the span. In the bridge's closed position, the end lift shoes rest on seats that are bolted to the abutment. When resting on the seat, the shoe acts as a rocker bearing, with small rotations accommodating thermal expansion and contraction of the span. The Milwaukee Road was probably the first American railroad to use this arrangement.[53] The rocker might not exert enough frictional force to keep the bridge from rotating, however, so Bridge No. Z-2's designers provided a draw-bar to lock the end in place. The draw-bar drops vertically from the bridge into a slot on the abutment. This is an improvement over nearby Bridge No. Z-6, where the draw-bar slides horizontally. The vertical draw-bar is more desirable because gravity will keep it in place if the mechanism fails.

The bridge machinery was controlled from a wooden operator's house attached to the span, 11'-0" by 5'-3" in plan with a shed roof, located on the west side of the bridge over the pivot pier.[54] Although the house no longer stands, the steel brackets that supported it still cantilever out from the pivot drum. On Bridge No. Z-2, a longitudinal shaft running the full length of the bridge transmitted power from a motor located inside the drum to the lifts and locks at the free end of the bridge. The railroad evidently replaced the end-most floor beam (at L0) subsequent to the bridge being rendered inoperable. The gearing, which had been attached to the old floor beam, was removed and not replaced. Nonetheless, part of a worm pinion remains, indicating that the span lock draw-bar may have been lifted and lowered by a worm gear. Bevel pinions and bevel gears, of which no trace remains, most likely turned a transverse shaft to rotate the end lift shoes.

The pivot on Bridge No. Z-2 is of the rim-bearing type, wherein a ring girder rides on a circular nest of wheels to carry the bridge's entire weight. At the center of this ring, a pin maintains the radial alignment. The eight radial girders that connect the pin to the ring girder are horizontal and taper toward the center, indicating a conscious effort to prevent the transfer of vertical load to the center. This is unusual considering that a majority of early twentieth-century swing spans were center-bearing, in fact, 73 percent of railroad bridges built from 1903 to 1923. In the Mississippi River basin, however, Chicago's Rush Street Bridge in 1856 set an early precedent for rim-bearing swing bridges.[55] This statistic appeared in a treatise that also cited a

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[52] See, for example, the machinery cuts in Charles H. Wright, *The Designing of Draw-Spans,* 1st ed. (New York: John Wiley & Sons, 1898).

[53] Hovey, *Movable Bridges,* 2:291.

[54] Chicago, Milwaukee & St. Paul Railway, Bridge and Building Department, "Z-2 Swing Bridge at Chicago, Operator's House," Drawing No. A-2521 (30 Aug. 1902), Album No. 93A, Canadian Pacific Railroad, Minneapolis, Minn.

[55] Hovey, *Movable Bridges,* 1:37-39.

number of reasons for the center-bearing type's superiority. Local preference for rim-bearing designs may have overruled some of the arguments against them. For example, although the wheels and track of a rim-bearing bridge must have a near-perfect conical surface for smooth operation, the Milwaukee Road's machine shops proved themselves capable of this task on nearby Bridge No. Z-6. One hundred years later, that structure still operates smoothly.

On Bridge No. Z-2, the roller nest rides on a cast steel circular track at a radius of 9'-2-3/8". Each of the forty rollers in the nest is held in place by a radial axle, connected back to a casting that rotates about the center pin. The track, fixed to the concrete pivot pier, also incorporates a circular rack for turning the bridge. A 220-volt, 25-horsepower electric motor, since removed from its location inside the ring girder, provided the power.[56] The motor, via a pinion and reduction gear, powered a longitudinal shaft equipped with a cable-operated brake. This shaft turned a spur pinion, which transmitted power through a torque equalizer to two horizontal operating shafts lying along the bridge's center-line. Each of these operating shafts, through a bevel pinion and bevel gear, turned a vertical operating shaft. Pinions at the base of both vertical operating shafts rotated the bridge by engaging the stationary circular rack. Each vertical operating shaft also has a spur pinion and spur gear operated by a hand crank from the bridge deck.

Conclusion

The Milwaukee Road's Bridge No. Z-2 has since changed owners, and no longer operates as a movable bridge, but still serves an active rail line. In 1985, the Minneapolis, Sault Ste. Marie & Atlantic Railway (Soo Line) acquired the Goose Island spur, among other Milwaukee Road properties in Chicago.[57] The Canadian Pacific Railroad (CP) had acquired the Soo Line as its U.S. division in 1888, an arrangement which continues at present.[58] Locomotives with either Soo Line or CP markings continue to move local freight trains across the bridge. The bridge's rail and end lifts, and the operator's house, were removed some time after the Army Corps of Engineers dropped the North Branch Canal from its list of navigable waterways. Without them, the span cannot be rotated. The railroad likely did not want to bear the expense of staffing the bridge, or the liability for its accidental movement.

The neighborhood today contains active industry, albeit among abandoned industrial buildings since remodeled for housing and retail. Working steel mills and scrap yards line Elston

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[56] For motor location, see Chicago, Milwaukee & St. Paul Railway, Bridge and Building Department, "Z-2 230 ft. Counterbalanced Swing Bridge," Drawing No. A-933 (11 July 1901), Album No. 93B, Canadian Pacific Railroad, Minneapolis, Minn.

[57] Gary U. Mentjes, Manager of Public Works for Soo District of Canadian Pacific Railway, telephone conversation with author, 15 June 1999.

[58] James E. Vance, Jr., *The North American Railroad: Its Origin, Evolution, and Geography* (Baltimore: Johns Hopkins Univ. Press, 1995), 278.

Avenue and Cortland Street, and the latter is decorated with landscaping and street furniture, indicating some investment by the city in improving neighborhood's appearance. Just east of Bridge No. Z-2, a branch of the Old Navy clothing store has appropriated a smokestack for a high-rise advertisement, a sign that industrial land use is on the wane. On Goose Island itself, heavier industries have been abandoned or demolished, and replaced by high-tech and light industry.

Amidst all this change, Bridge No. Z-2 sits rusting, visited by the occasional pedestrian or freight train. Although the operating mechanism has since been disabled, the remaining fabric provides a fairly complete picture of how the bridge worked. Its unusual bob-tail design remains a testament to the ingenuity of the Milwaukee Road's bridge engineers. Furthermore, as one of a declining number of railroad bridges in downtown Chicago, it serves as a reminder of the city's — and Goose Island's — industrial past.

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